

LINEAR SPEED OF CMEs IN RECENT SOLAR MAXIMA.

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Abstract : The spacecraft SOHO observed Coronal mass ejection(CME) from Sun. The study analysed the classification of CMEs by its statistical property; linear speed during 23 and 24 solar cycle maximum. This will help to elucidate the nature of different types of CMEs ejecting during the Solar cycle. The highest activity phase of solar cycle 23 and 24 produced a large number of highly energetic CMEs. Hence try to analyse and classify the various types of CMEs by the property; linear speed.

IndexTerms – Solar wind, Coronal mass ejection(CME), Linear speed.

I. INTRODUCTION

Coronal mass ejections (CMEs) interact with earth atmosphere and gives several phenomenon. CMEs are a topic of extensive study, since they were first detected in the coronagraph images obtained on 14-December-1971 by NASAs OSO-7 spacecraft (Tousey, 1973). In fact, CMEs are large scale magnetized plasma structures ejected from regions where the magnetic field lines of the Sun are closed, such as active and filament regions, active region complexes and trans-equatorial interconnecting regions. It has been recognized that such ejections should carry magnetic fields (Gold, 1962). The coronal mass ejections are spectacular manifestations of the erupting solar magnetism. They are the pieces of the Sun that travel in space and carry the solar activity out from the star. The solar activity has a fundamentally magnetic nature and so, the coronal mass ejections (CMEs) are magnetic phenomena. Coronal mass ejections represent one of the major events important for the solar activity action on the interplanetary space and consequently on our planet. (Gosling et al., 1976). With a kinetic energy that may exceed 10^{32} ergs, it is one of the most energetic forms of solar activity. CMEs entered the modern era with the Skylab observations (Gosling et al., 1974; Munro et al., 1979). Since the discovery of CMEs, there are many investigations carried with the statistical properties of CMEs (Hundhausen, 1993; Howard et al., 1985; Gopal swamy, 2004, 2006a,b; Kahler 2006; Gopalswamy, 2009; Gopalswamy et al., 2010; Bidhu et al. 2016,2017). Linear speed, angular width, latitude, acceleration, occurrence rate, energy and halo CMEs are the statistical properties of CMEs. Among these linear speed of CMEs is taken for the analysis during 23 and 24 solar cycle maximum. CME score classification system gives the brilliant idea about the observation of SOHO CME. SCORE indicates the type of the detected CME based on the transient speed (<http://sw.pc.noaa.gov>). Classification is based on the rate of occurrence of CMEs and thus gives the user a quick idea about the likelihood of the observed event.

The figure 1 represents the CME score classification system based on CDAWeb SOHO LASCO catalogue, linear speed. (Evans et al., 2013). The various types CMEs with linear speed of CMEs observed by SOHO LASCO instrument from 1996 till

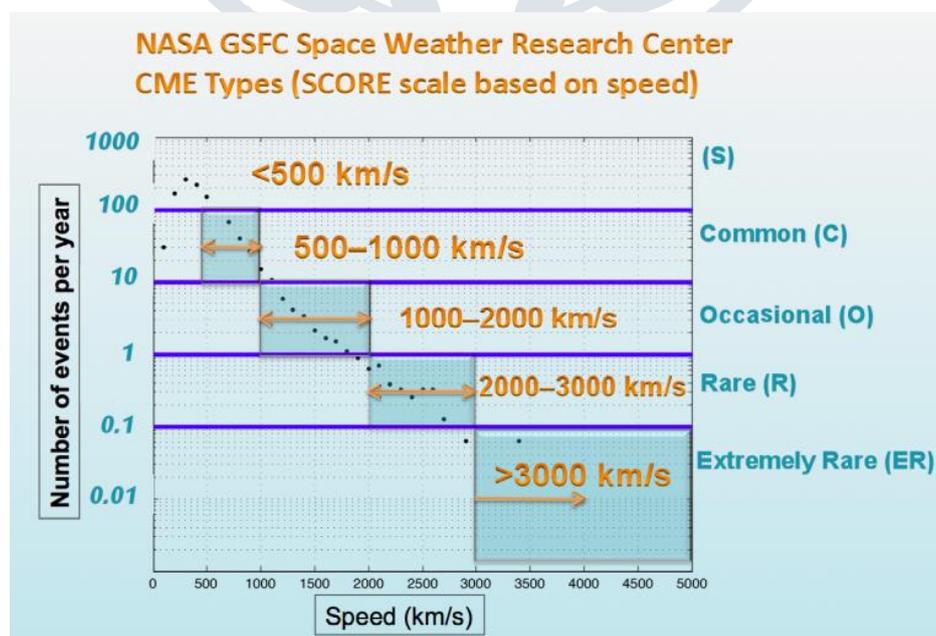


Figure 1: CME score classification system(Data: CDAWeb SOHO LASCO catalogue, linear speed)

2015; (the 23 and 24 solar cycle) is taken for the study. The study analysed the classification of CMEs by linear speed. This will help to elucidate the nature of different types of CMEs ejecting during the Solar cycle. The most intensive geomagnetic activity is due to the energetic CMEs. The highest activity phase of solar cycle 23 and 24 produced a large number of highly energetic CMEs. Hence try to analyse and classify the various types of CMEs by their physical property; linear speed.

II. DATA

The SOHO mission's LASCO instrument routinely records CMEs. The CME catalog, generated and maintained at the CDAW data center, NASA Goddard Space Flight Center, covered the period from January 1996 to present. It had detected more than 12970 CMEs during 1996-2007 period and 12940 CMEs during 2008-2015 period which had been catalogued on website <http://cdaw.gsfc.nasa.gov/CMElist>. For each event, the catalogue contains height-time plots (fitting measurements of the apparent height of a morphological feature at different times, a height-time diagram), plane of sky speeds (The speed with which the CME spreads in the sky plane) and the corresponding accelerations. The CME speeds were determined from both linear and quadratic fit to the height-time measurements. The speed of CME was usually measured by constructing a time-height diagram for the fastest moving feature of the CME front as it projected on the plane of the sky. The plane of the sky values can be deviated from the real radial speed of the CME front, depending on the actual direction of the motion. This study analyzed that the linear (constant speed) fit was preferable for 90% of the CMEs. It may be remarked that there was a data gap during the period July-Sept., 1998, because during this period SOHO satellite became inoperational (Gopalswamy et al., 2009). The SOHO/LASCO continuously recorded CMEs using its two telescopes C 2 and C 3. The C 1 telescope which can observe CMEs closer to the sun was disabled in June 1998.

III. LINEAR SPEED OF CMES IN 23 AND 24 SOLAR CYCLE

It was accepted that magnetic reconnection plays a major role in the origin of a coronal ejection, which were driven through the ambient solar wind by magnetic and pressure forces (Vršnak, 1990; Chen, 1996). CMEs propagating in the interplanetary space, asymptotically approach the wind velocity due to the viscous drag high in the corona (Gopalswamy et al., 2001; Wu et al., 2002; Vršnak and Gopalswamy, 2002; Vršnak et al., 2013). We would like to note here that the origin of CMEs and their propagation in the solar corona and interplanetary space were complex. The problem of the existence of CMEs can be solved by analysing their statistical. Recently, (Aoki et al., 2003) used the log-normal distribution to fit X-ray peak fluxes of 254 solar flares and speeds of the associated CMEs. 23 solar cycle begins in the month of May, 1996 and ends with 2008 January. This was 11.8 year long cycle. The 23 SC minimum occur at during may to october 1996. Solar cycle 24 started in January 2008 and still goes on. Solar cycle 23 peaked in 2000-2002 with many furious storms. Solar cycle 24 peaked in 2009-2012. Solar cycle 24 has initially displayed much less activity. Generally, CME speed lied between 200 km s^{-1} and 2000 km s^{-1} , CMEs speed below 400 km s^{-1} speed were accelerated and CMEs above 400 km s^{-1} were decelerated by solar wind interaction (Manoharan, 2006). The figure 2 shows strong(S) CMEs in solar cycle 23 and figure 3 shows corresponding CMEs in 24 solar cycle. Minimum 140 number of strong CMEs in every year were observed by SOHO-LASCO in solar cycle 23.

CMEs more than 120 in number per year were observed during declining phase of 23 solar cycle, in minimum phase minimum number of S CMEs were observed. The more number of Strong CMEs (159) per month were detected in June 2007. But in the year 2007 more number of Strong CMEs per year were observed. About 10-100 S CMEs were observed in ascending and maximum phase in 23 solar cycle. But during 2001, a more number of strong CMEs were observed. Minimum 140 number of strong CMEs in every year were observed by SOHO-LASCO in solar cycle 24. The more number of S CMEs greater than 180 in

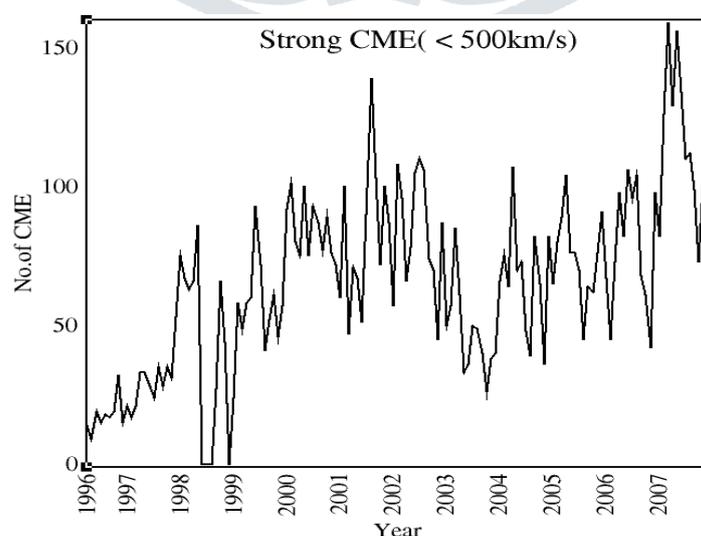


Figure 2: Strong CMEs in Solar cycle 23

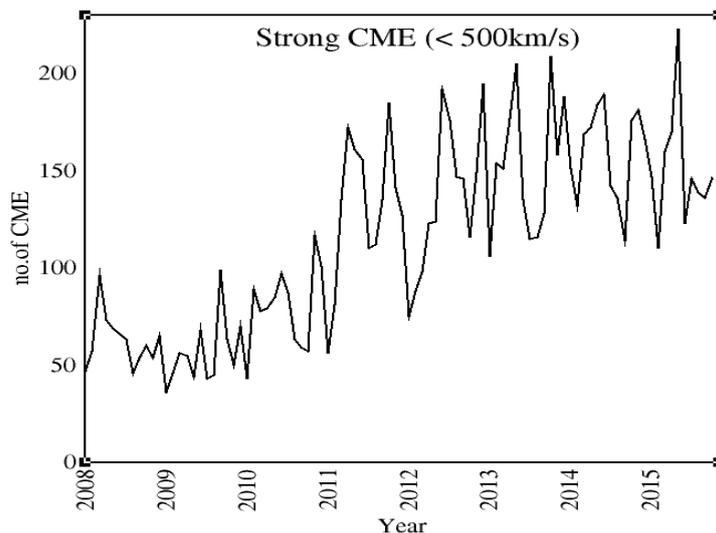


Figure 3: Strong CMEs in Solar cycle 24

number were observed during declining phase of 24 solar cycle, in minimum phase minimum number of S CMEs were observed. The more number of Strong CMEs (223) per month; were detected in June 2015. But in the year 2014 more number of Strong CMEs per year were observed. About 40-150 number of Strong CMEs were observed in ascending and 70-220 number of Strong CMEs in the maximum phase.

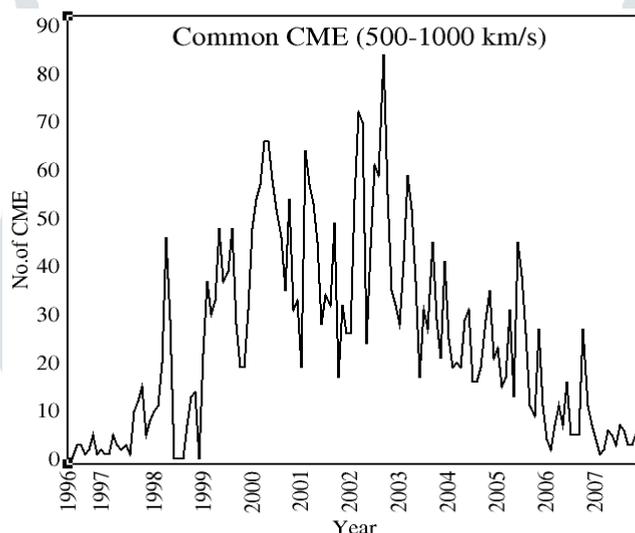


Figure 4: Common CMEs in Solar cycle 23

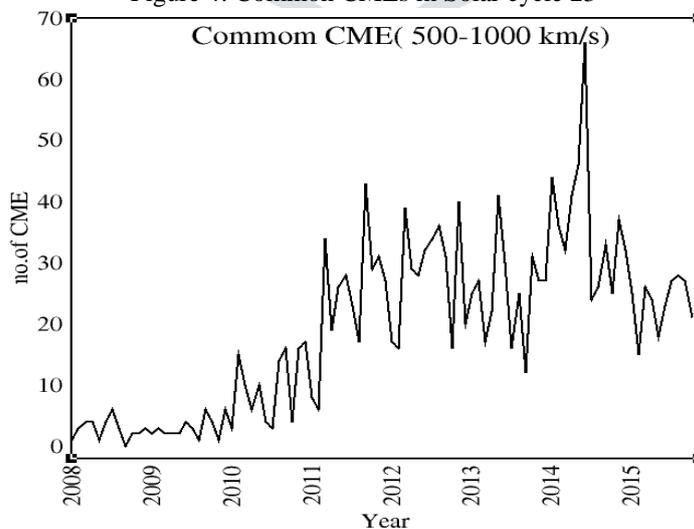


Figure 5: Common CMEs in Solar cycle 24

Common(C) CMEs observed in solar cycle 23 and 24 were illustrated in the figure .4 and 5. Both solar cycle observed more number of common CMEs emission during solar maximum phase. The emission of common CMEs increases from minimum phase to maximum phase, attains maximum number during solar maximum: nearly at second one of twin peak, then decreases towards declining phase. Minimum 50 number of strong CMEs in every year were observed by SOHO-LASCO in solar cycle 23. About 2 - 50 Common CMEs were observed in ascending and 20-90 Common C in maximum phase in 23 solar cycle. Minimum 30 number of strong CMEs in every year were observed by SOHO-LASCO in solar cycle 24. The more number of Common CMEs (223) per month; were detected in October 2002. But in the year 2000; more number of Common CMEs per year were observed in 23 solar cycle. In 24 solar cycle; the more number of Common CMEs (66) per month; were detected in June 2014. Also in the year 2014; more number of Common CMEs per year were observed.

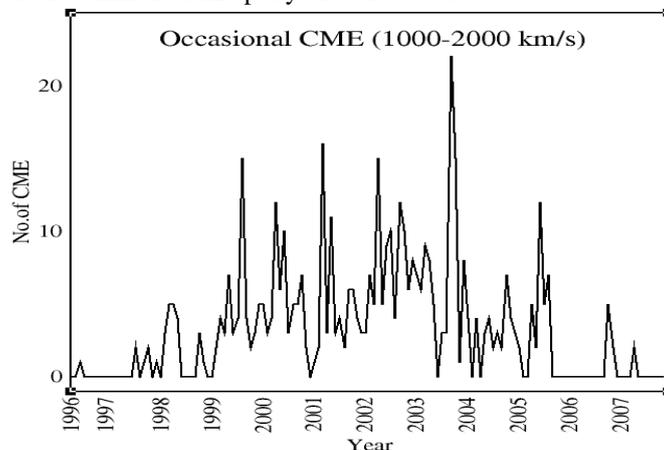


Figure 6: Occasional CMEs in Solar cycle 23

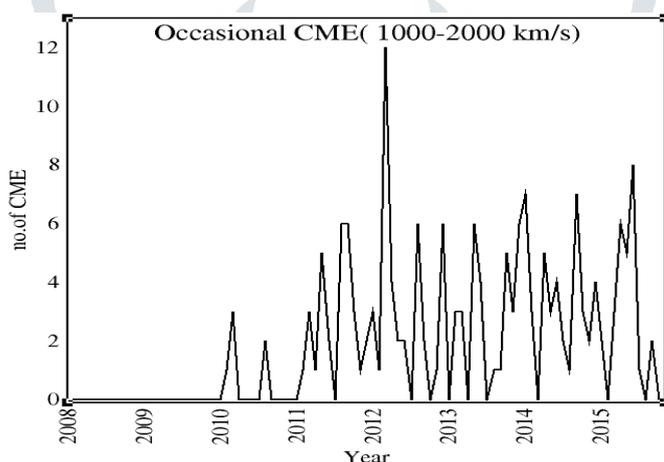


Figure 7: Occasional CMEs in Solar cycle

The figure 6 shows occasional(O) CMEs in solar cycle 23 and figure 7 shows corresponding CMEs in 24 solar cycle. Minimum 2 number of Occasional CMEs in every year were observed by SOHO - LASCO. In solar cycle 23, the more number of Occasional CMEs (22) per month; were detected in October 2003. But in the year 2004; more number of Occasional CMEs per year were observed. The occasional CMEs were mostly emitted during the solar maximum phase of this cycle. There was no such emission of occasional CMEs were found in 2008 and 2009, the declining phase of solar cycle 23. In SC 24, the more number of Occasional CMEs per month; were detected in first twin peak of maximum phase. But more number of Occasional CMEs per year were observed in the second twin peak.

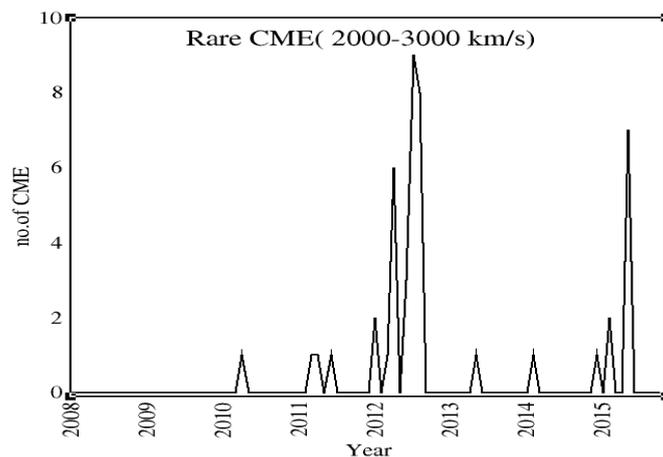


Figure 8: Rare CMEs in Solar cycle 23

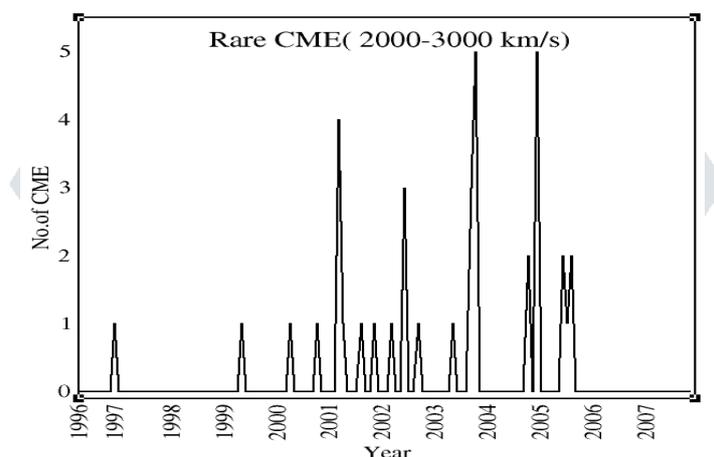


Figure 9: Rare CMEs in Solar cycle 23

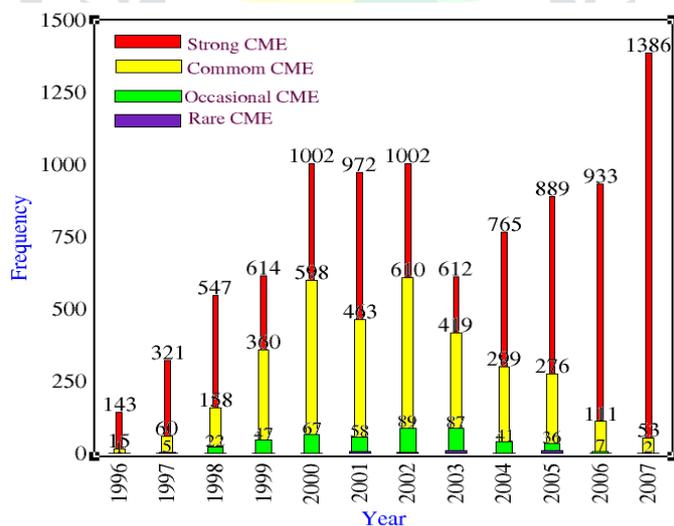


Figure 10: Annual statistics of CMEs (linear speed) in Solar cycle 23

Figure 11: Annual statistics of CMEs (linear speed) in Solar cycle 24

Figure 11: Annual statistics of CMEs (linear speed) in Solar cycle 24

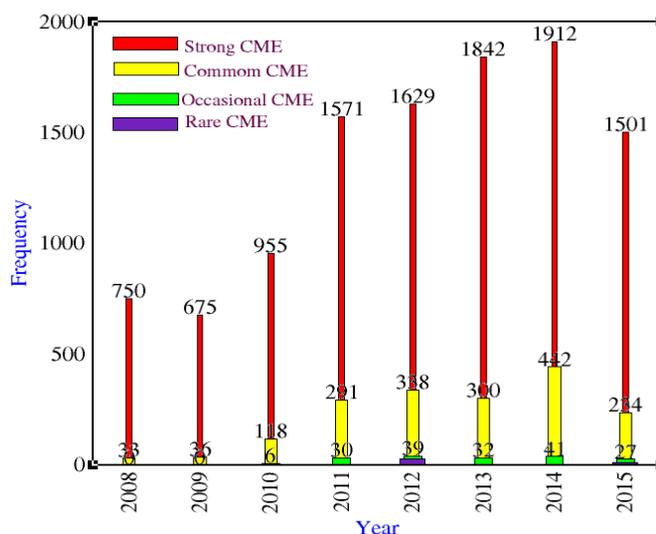


Figure 11: Annual statistics of CMEs (linear speed) in Solar cycle 24

CME	23 Solar Cycle (%)	24 Solar Cycle (%)
Strong CMEs	70.04	84.33
Common CMEs	26.01	13.94
Occasional CMEs	3.67	1.46
Rare CMEs	0.28	0.36

Table 1: Percentage of CMEs (linear speed) in solar cycle 23 and 24

Table 1 show the percentage of CME Score classification in solar cycle 23. solar cycle 24 observed more percentage of Strong type CMEs than in 23 solar cycle. The percentage of Common and Occasional CMEs were more in 23 solar cycle than in 24 solar cycle. But the the rare CMEs were more observed in 24 solar cycle than 23 solar cycle.

IV. CONCLUSION

The classification of CMEs physical properties; linear speed was analysed for 23 and 24 solar cycle. The strong coronal mass ejections were rich in solar cycle 24, weaker solar cycle than the solar cycle 23. Common, occasional and rare coronal mass ejections were plentiful in solar cycle 23 and 24. But in solar minimum phase, both solar cycles eject less number of CMEs. Variability of CMEs over a time in the order of days were the one of the great attribute of solar wind. In solar cycle 23, maximum number of strong CMEs were found in the ascending phase; in 2007 and the more number of common and occasional CMEs were found in maximum phase; in 2002 and 2003 respectively. In solar cycle 24, maximum number of strong CMEs were found in the minimum phase; in 2008 and the maximum number of common and occasional CMEs were found during maximum phase. The Rare CMEs were hardly found in minimum and ascending phase and existed in maximum and declining phases of both 23 and 24 solar cycles.

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